Muon Wheel/Disk Alignment Constants from HIP

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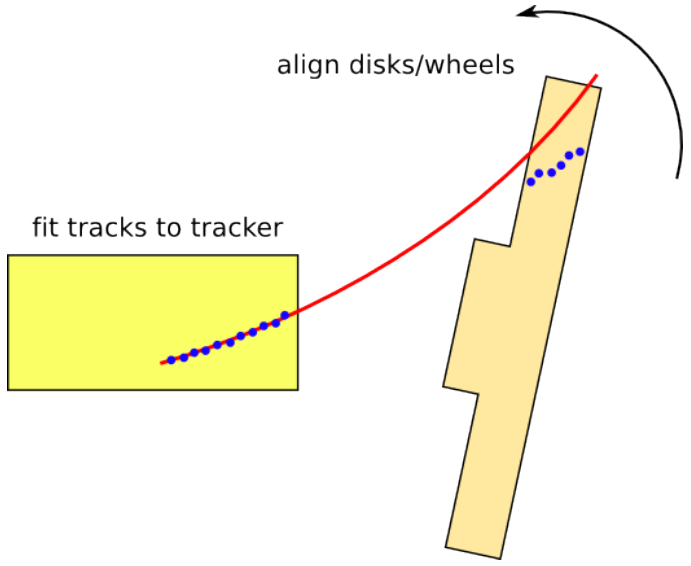
Outline

- Reminder of method
- Alignment results

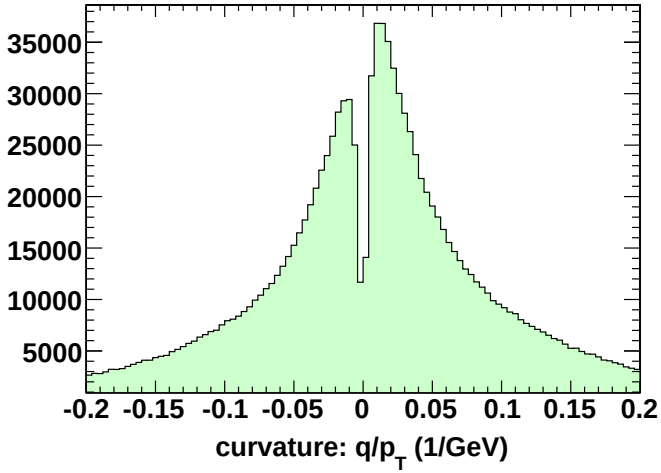


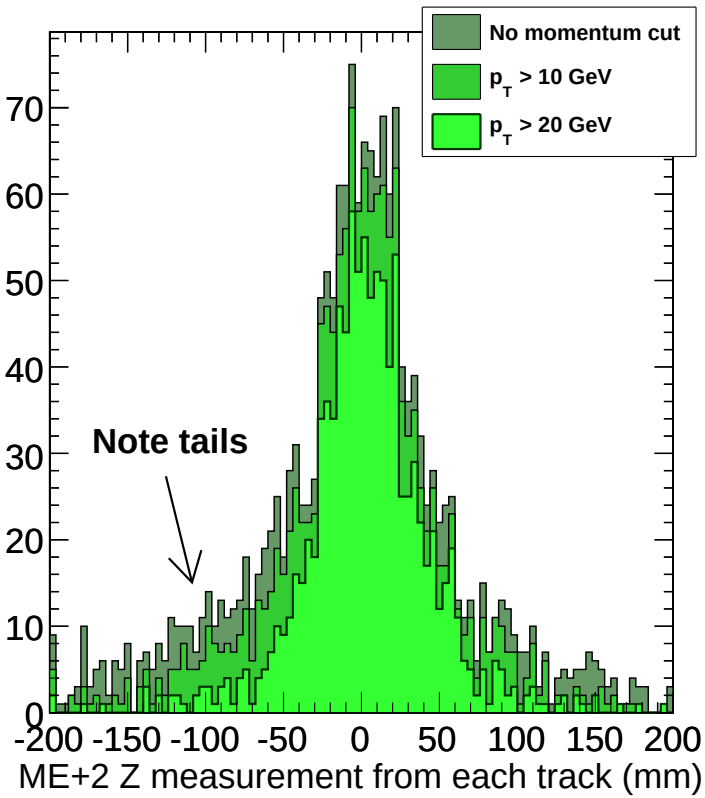
Reminder of method

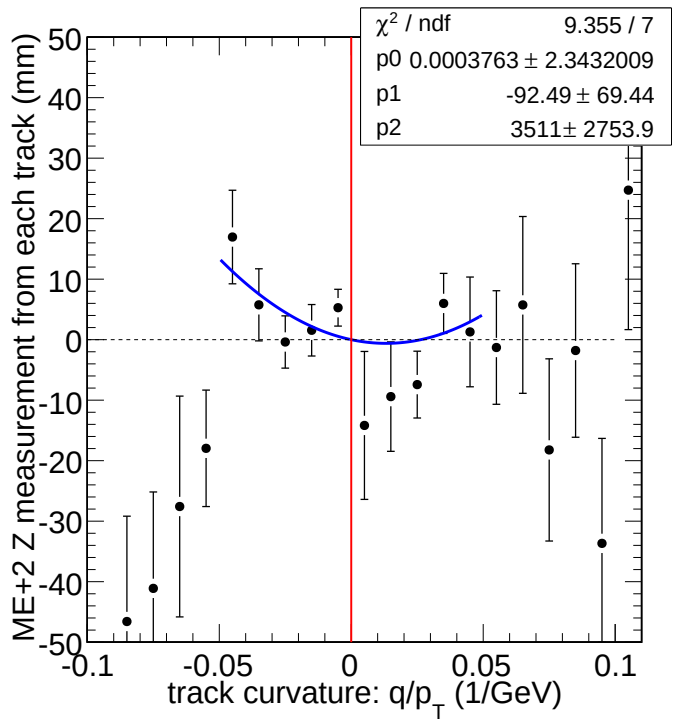
- Treat 5 barrel wheels and 6 out of 8 endcap disks as 6-dof rigid bodies
- Select CRAFT global cosmic rays passing through tracker and wheel/disk
- Fit tracker part, propagate to wheel/disk, align wheel/disk
  - ME$\pm$4/1 and inner rings (ME$\pm$1/1, 2/1, 3/1) are nearly inaccessible (dozens of poor-quality tracks)
  - track-fitting and alignment step are independent
- Every track residual can be converted into 6-dof alignment corrections

Selecting tracks by p_T

- CRAFT offers new ability to reject low-momentum tracks
- Observe each alignment parameter as a function of curvature (q/p_T)
- Cleanest measurement is above 20 GeV



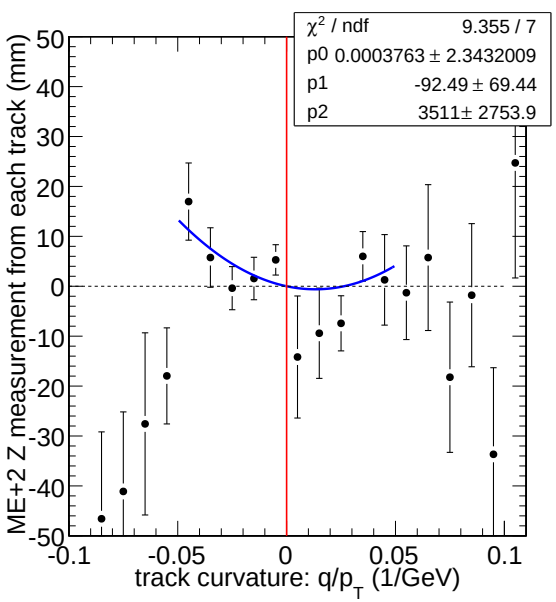




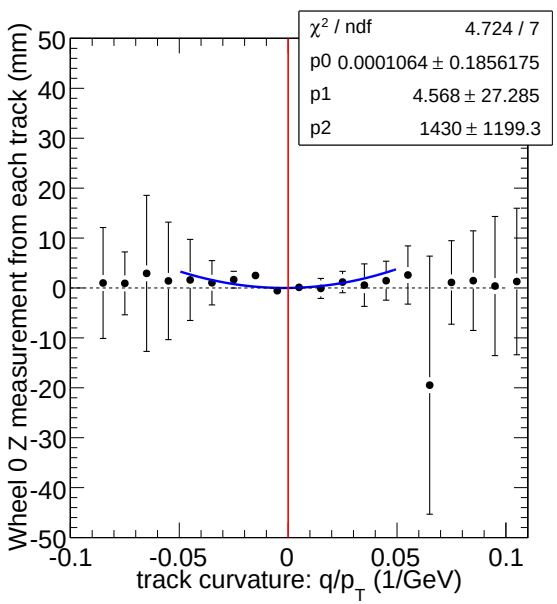
$p \to \infty$ extrapolation

- Multiple scattering and $\vec{B}$ errors limit to zero at infinite momentum
  - multiple scattering is symmetric (independent of q)
  - $\vec{B}$ errors are antisymmetric with q
  - both depend on track angles and detailed track distribution
- Taylor-expand around $q/p_T = 0$ up to second order
- Constant term (p_0) is the misalignment: alignment minimizes p_0
- Linear term (p_1) is $\vec{B}$ error, sensitive to a few percent of a Tesla

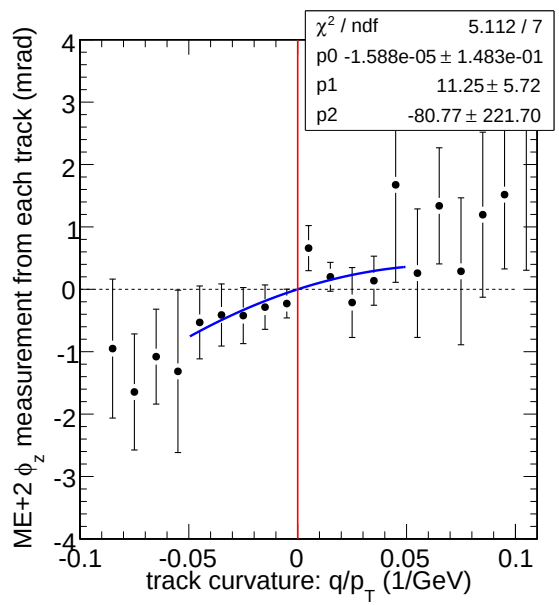
ME+2 z



Wheel 0 z



ME+2 ϕ_z

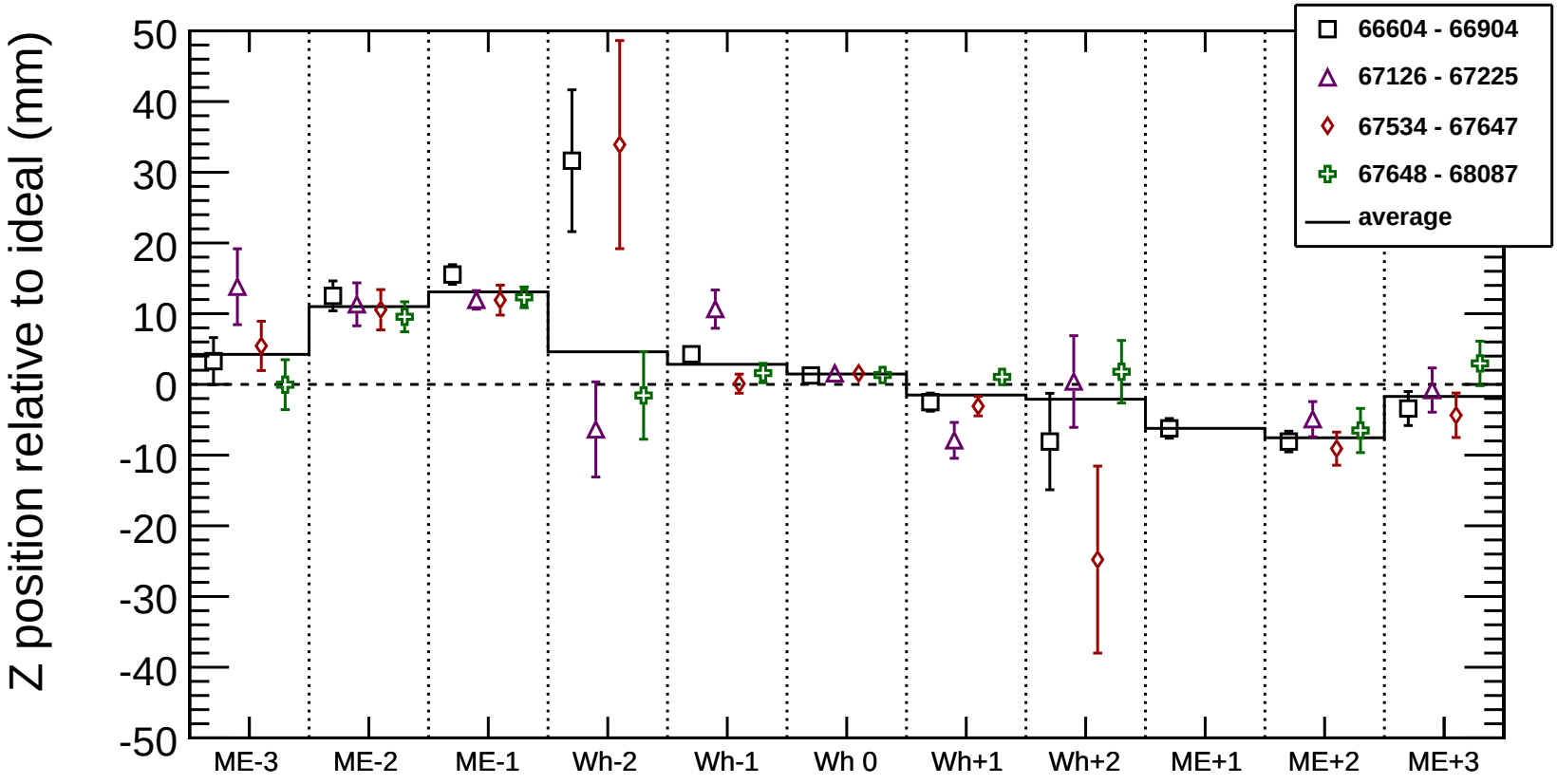


Details

- Iteration scheme: $2 \times \begin{pmatrix} z \\ \phi_z \end{pmatrix}$, followed by $4 \times \begin{pmatrix} x & y & z \\ \phi_x & \phi_y & \phi_z \end{pmatrix}$
  - only needed for resolving correlations among parameters: track-fits are already independent of muon alignment
- All barrel wheels converged, endcap disks only in $\begin{pmatrix} z \\ \phi_z \end{pmatrix}$ scheme
  - I think I only need to fix y for endcap (converged in early tests)
- Endcap disks aligned with tracks passing through outer ring only (allows inner ring correction to be applied from hardware measurement)
- Barrel wheels: weighted means
  Endcap disks: unweighted means (due to low statistics)
  - Barrel uncertainties are underestimated: switch back to unweighted means in future
- Quality cuts: tracker $\chi^2/N_{\text{DOF}} < 10$, $N_{\text{tracker hits}} \geq 10$, at least 500 tracks per alignable
- I check quality of each "parameter vs. q/p_T" fit manually

All alignment results (1/8)

- Four run regions with stable 3.8 T field
- Results depend on tracker alignment: this uses tracker-HIP with survey constraints
- Muon alignment uses tracks only (aligned is *contracted* relative to ideal)
- From the pattern, I do not believe run-by-run differences are real



All alignment results (2/8)

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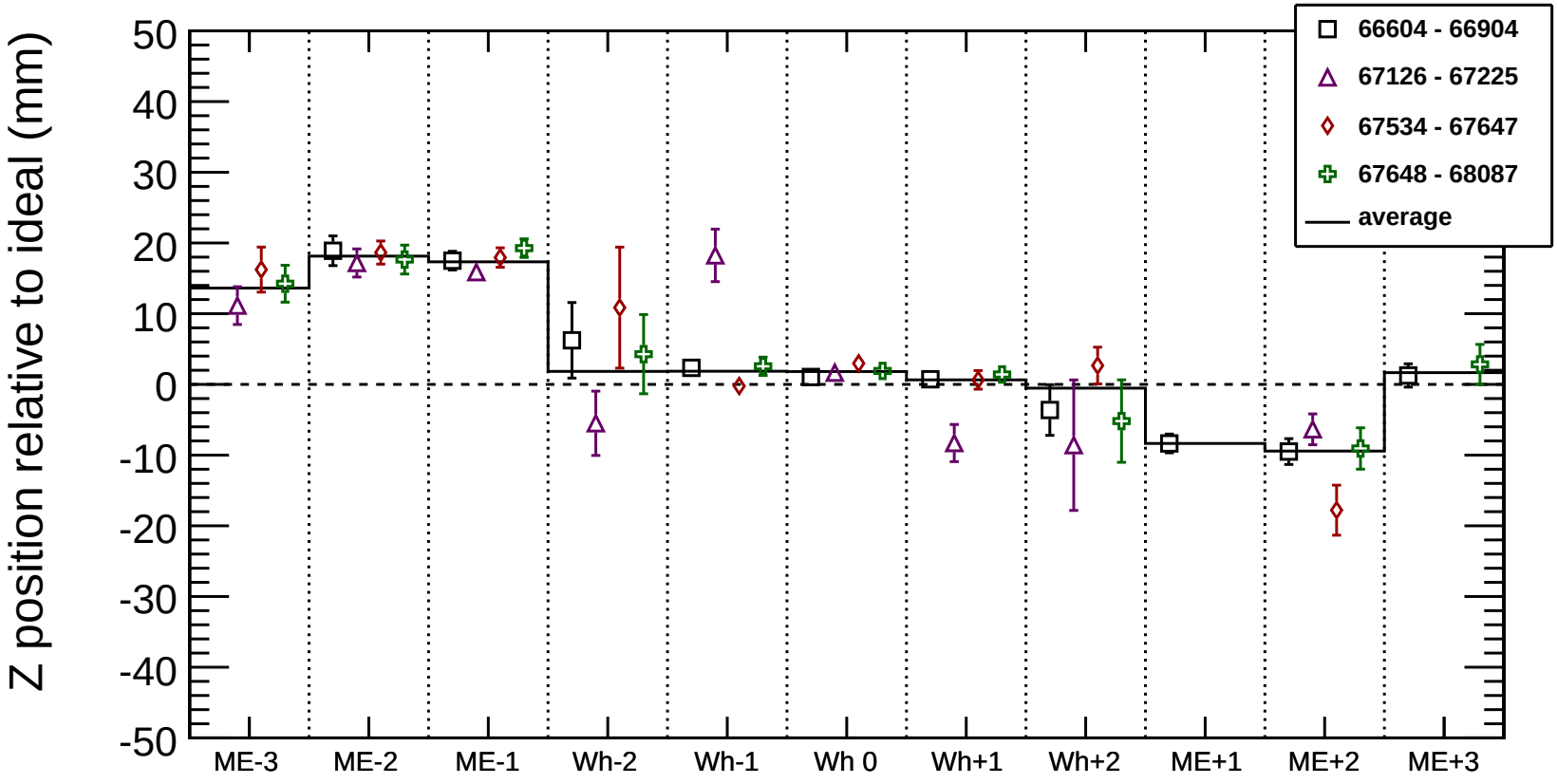

All alignment results (3/8)

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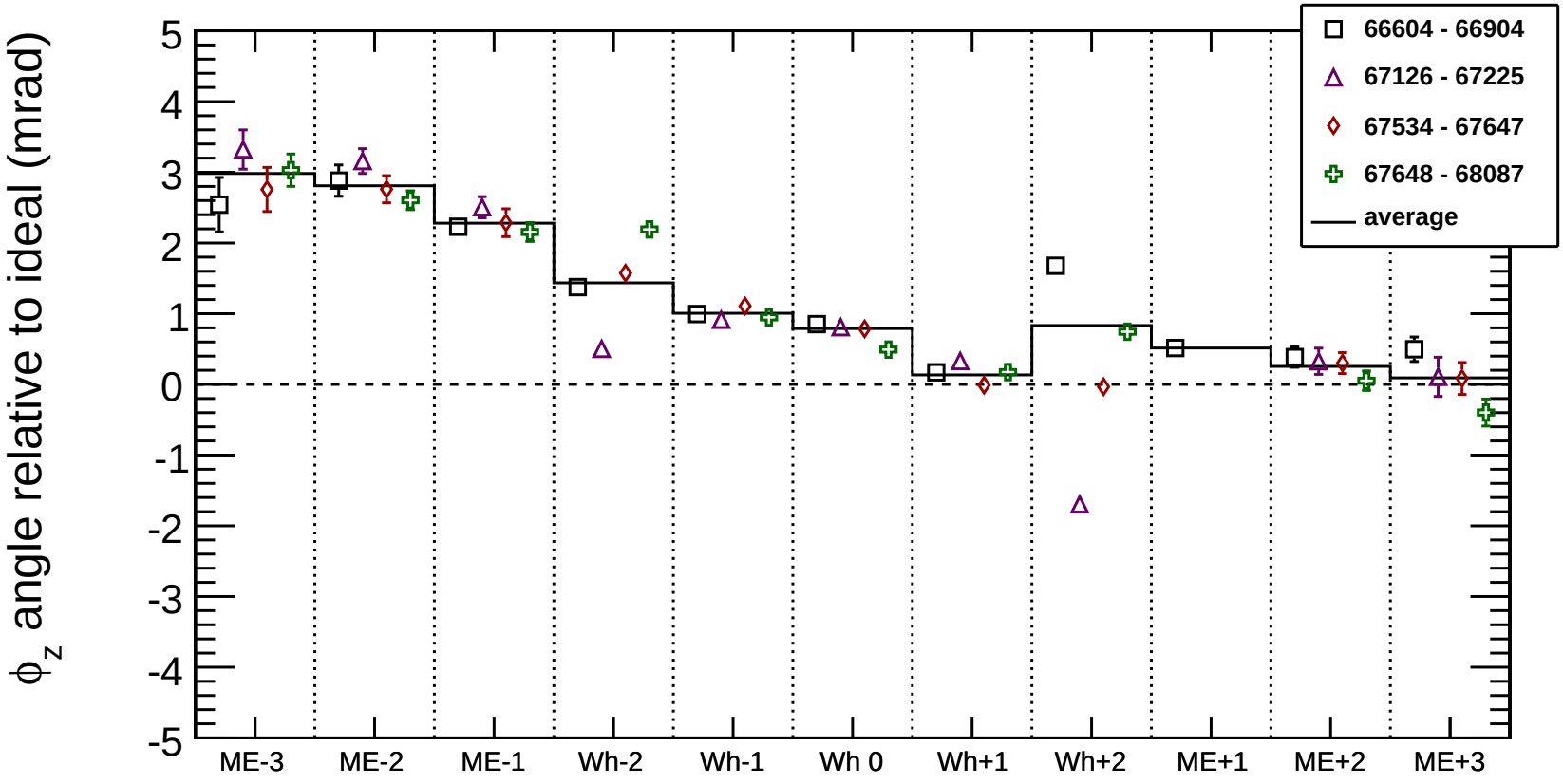

All alignment results (4/8)

- Four run regions with stable 3.8 T field
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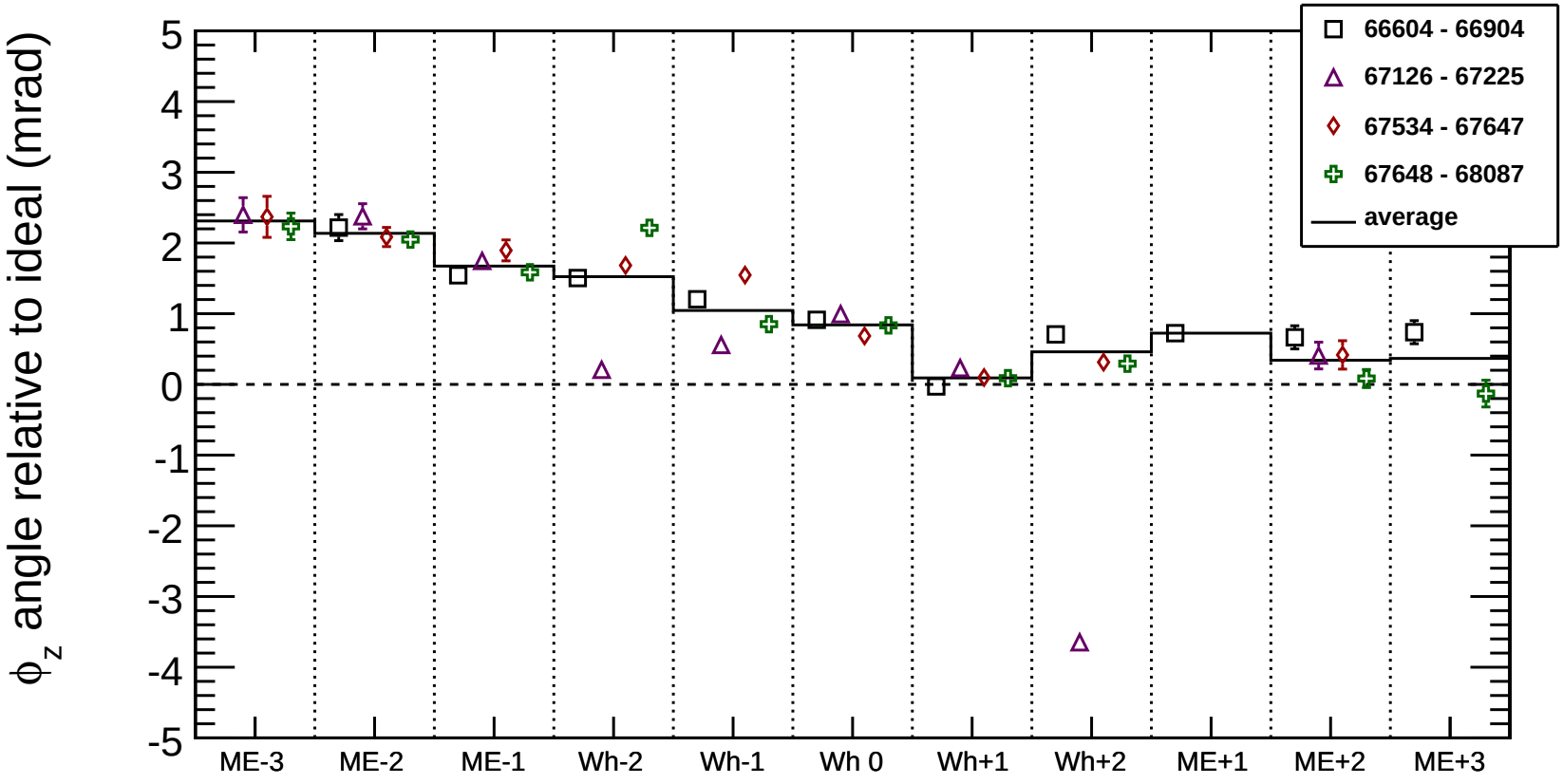

All alignment results (5/8)

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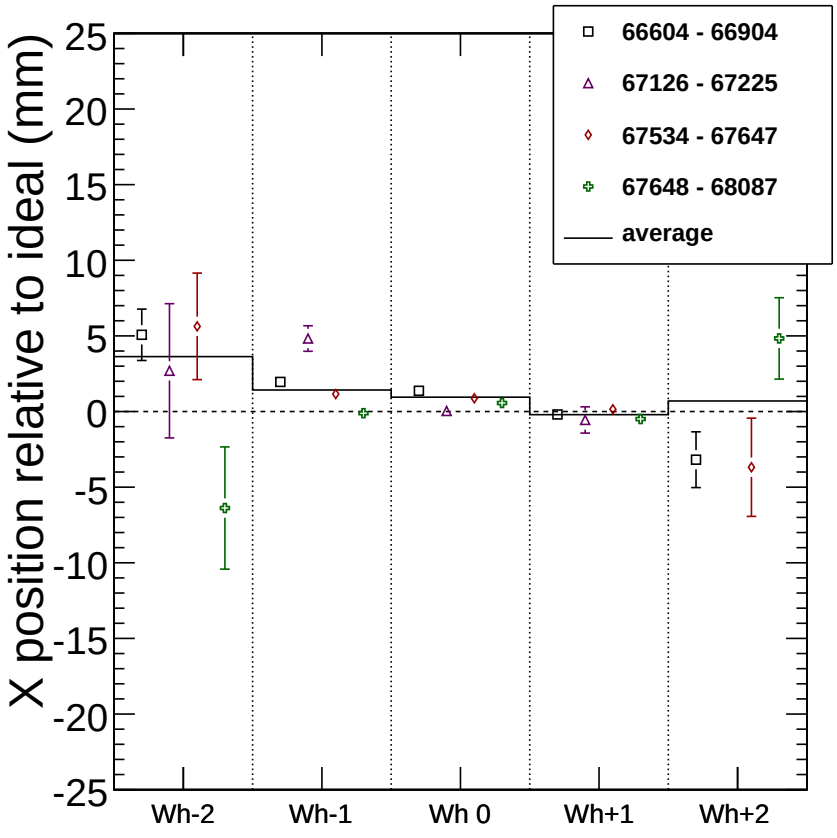

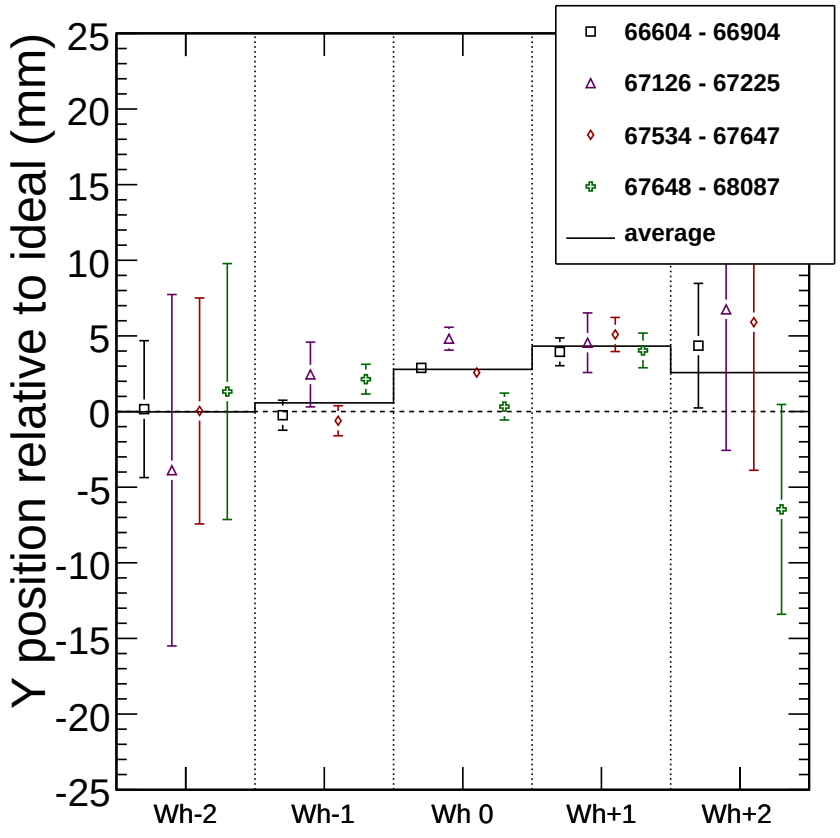

All alignment results (6/8)

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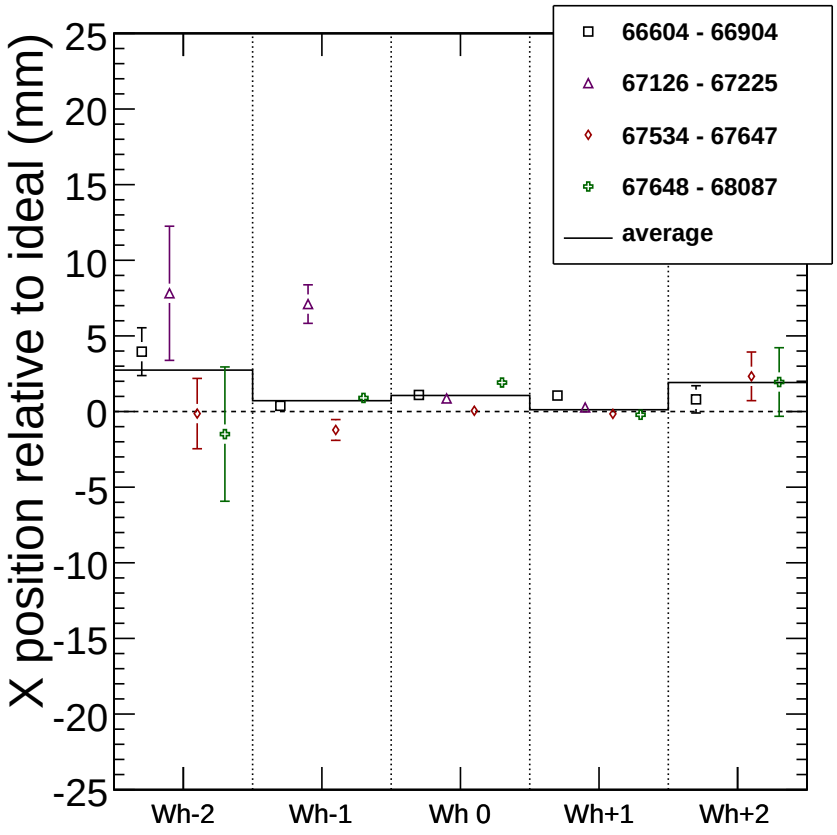

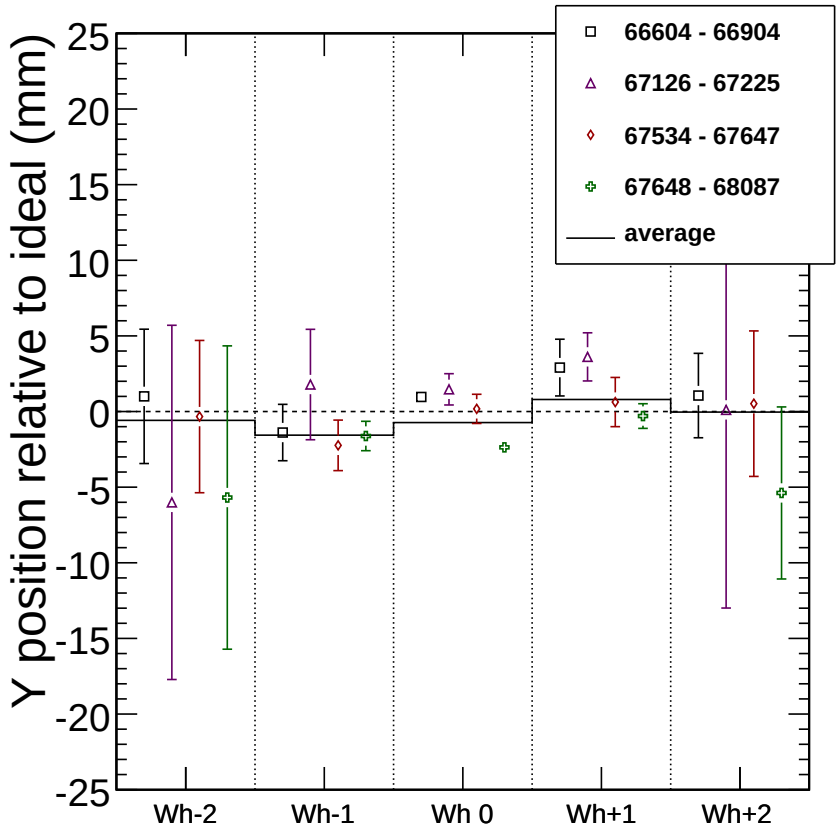

All alignment results (7/8)

- Four run regions with stable 3.8 T field
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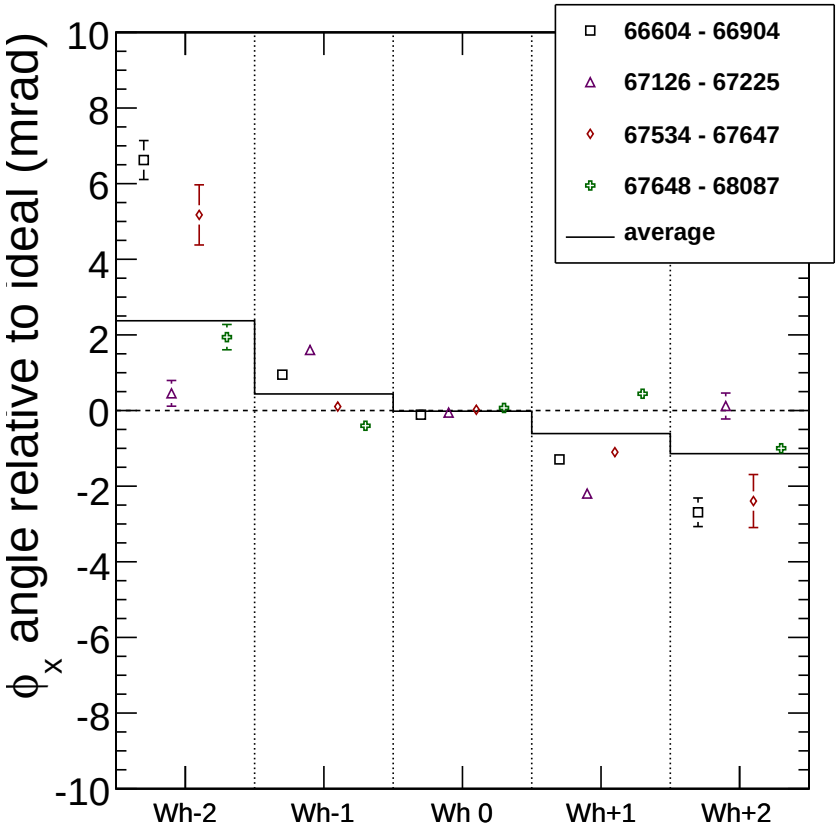

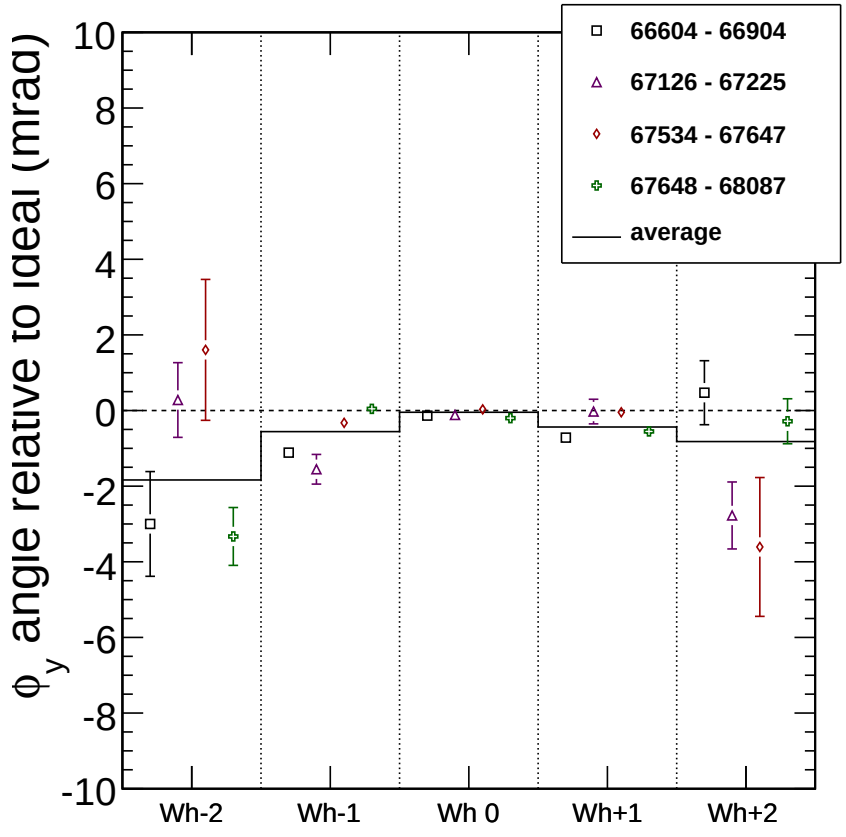

All alignment results (8/8)

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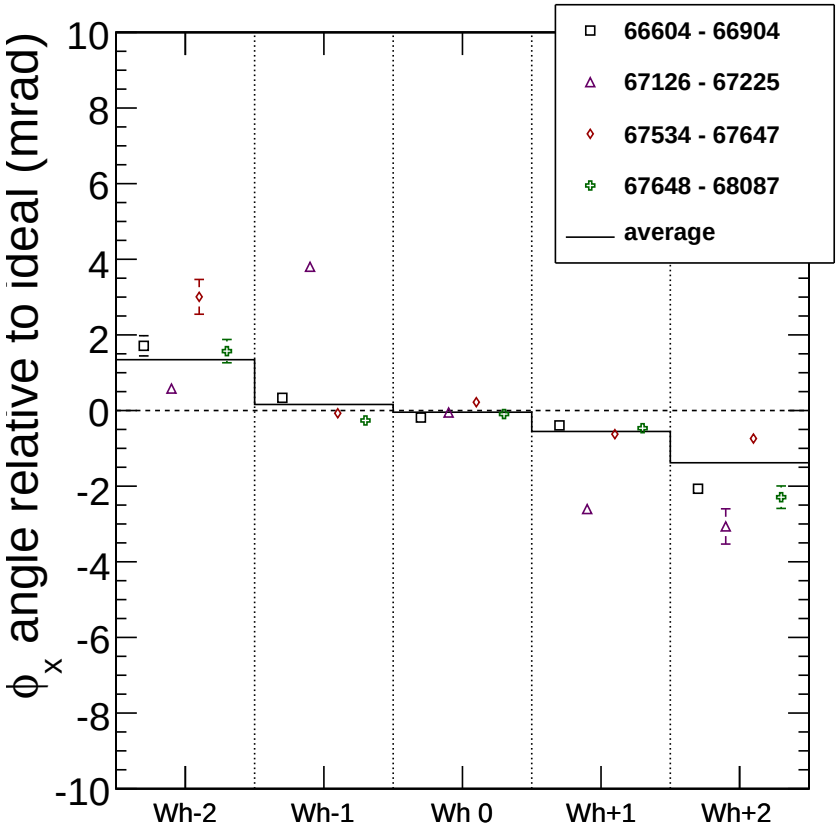
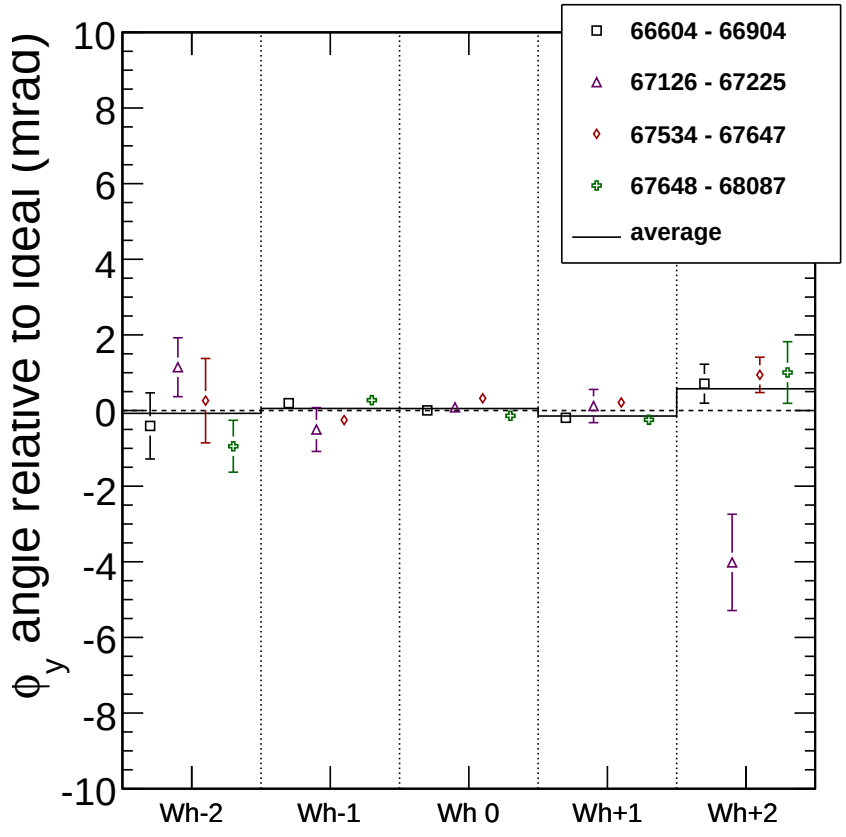


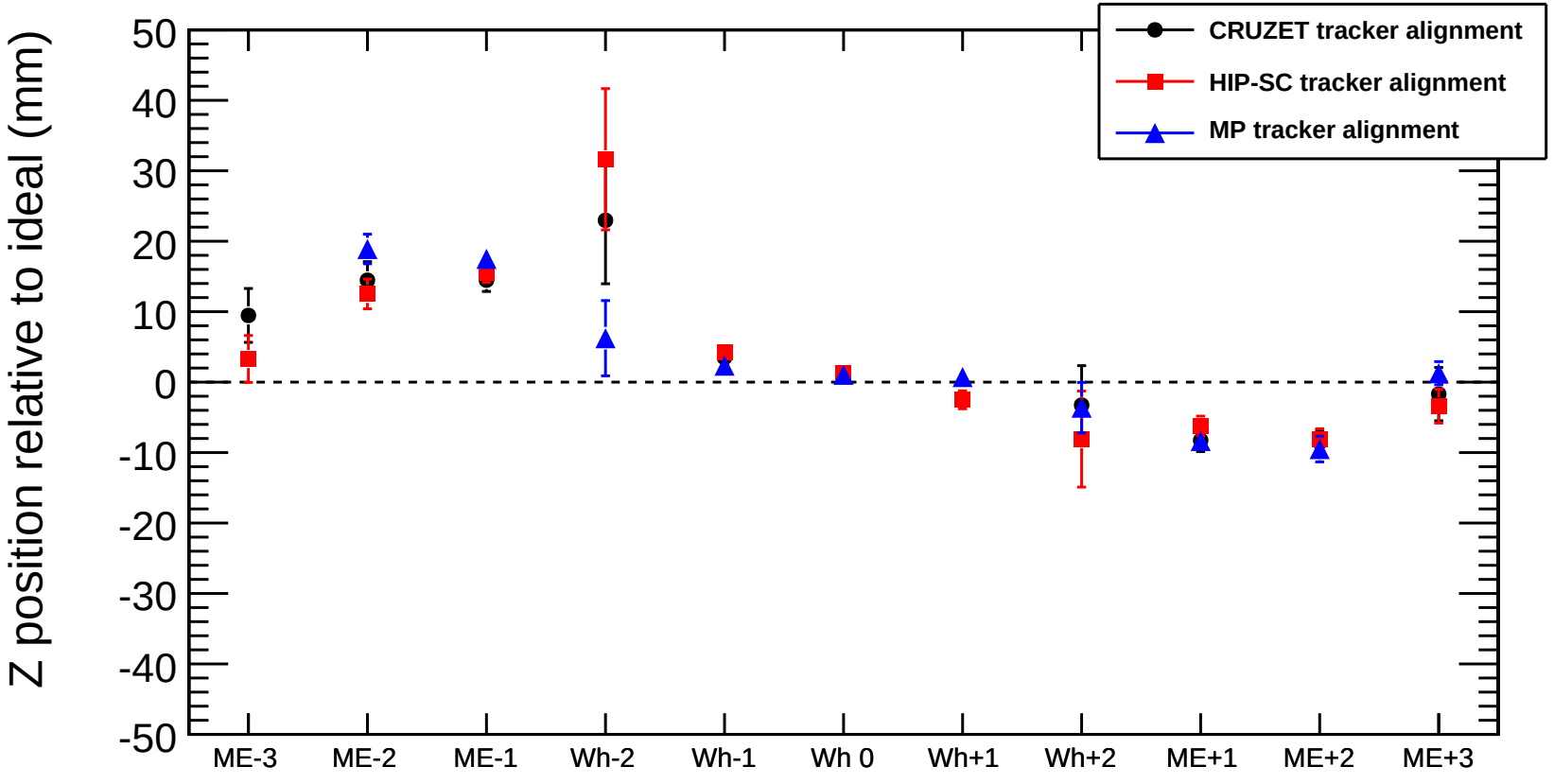


Conclusions

- Tracker MillePede alignment yields the most stable positions from one run range to the next
- Uncertainties appear to be underestimated in barrel: switch to unweighted means (less precise, more robust)
- Endcap will probably converge with $\begin{pmatrix} x & & z \\ \phi_x & \phi_y & \phi_z \end{pmatrix}$ floating
- Should be compared to survey/hardware
- Endcap results should be combined with hardware measurements of disk bowing, because inner rings are *extremely* statistics-limited in globalMuon cosmic rays
- Alignment takes about 5 hours on about 100 CPUs (depending on dataset): we have time to prepare another, including the above
  - Should four run ranges be combined? I think so.

Backup: tracker alignment study

- Largest run range (66604-66904)
- Compare results using tracker alignment from CRUZET, CRAFT HIP with Survey Constraints, and CRAFT MillePede
- Muon alignment is always MuonHIP, tracks only



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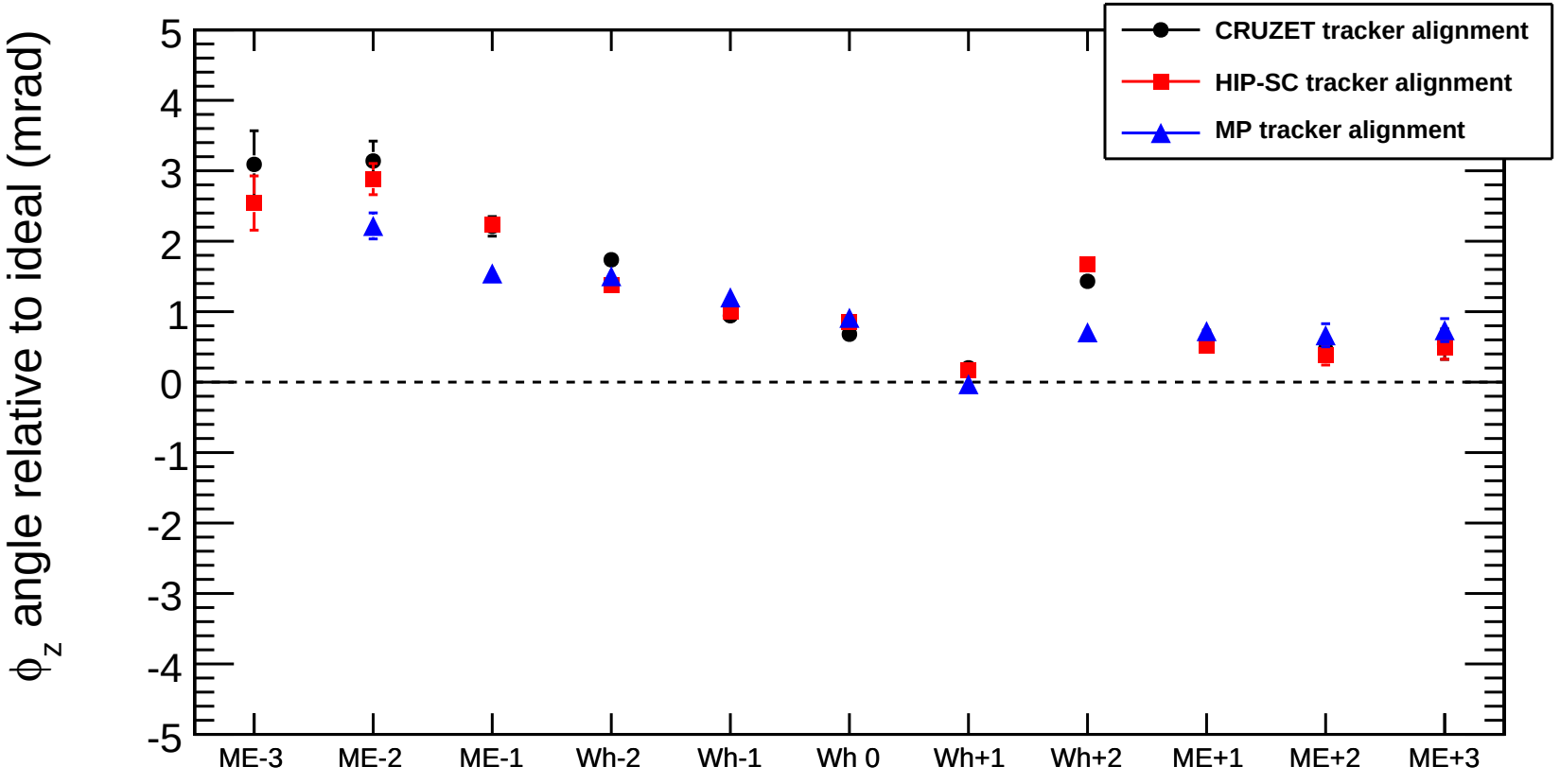

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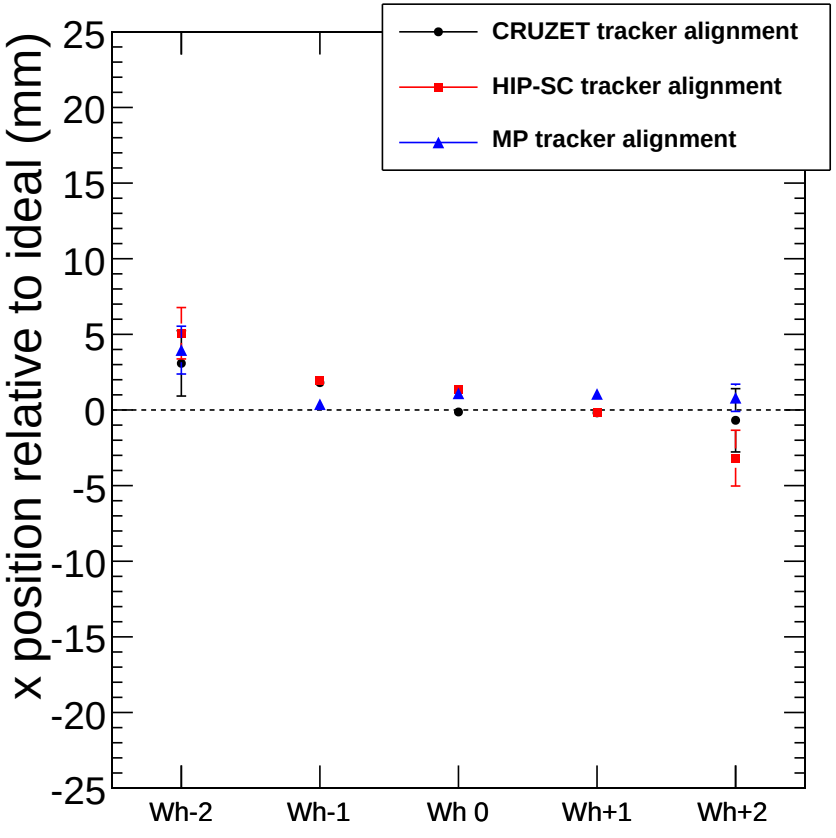

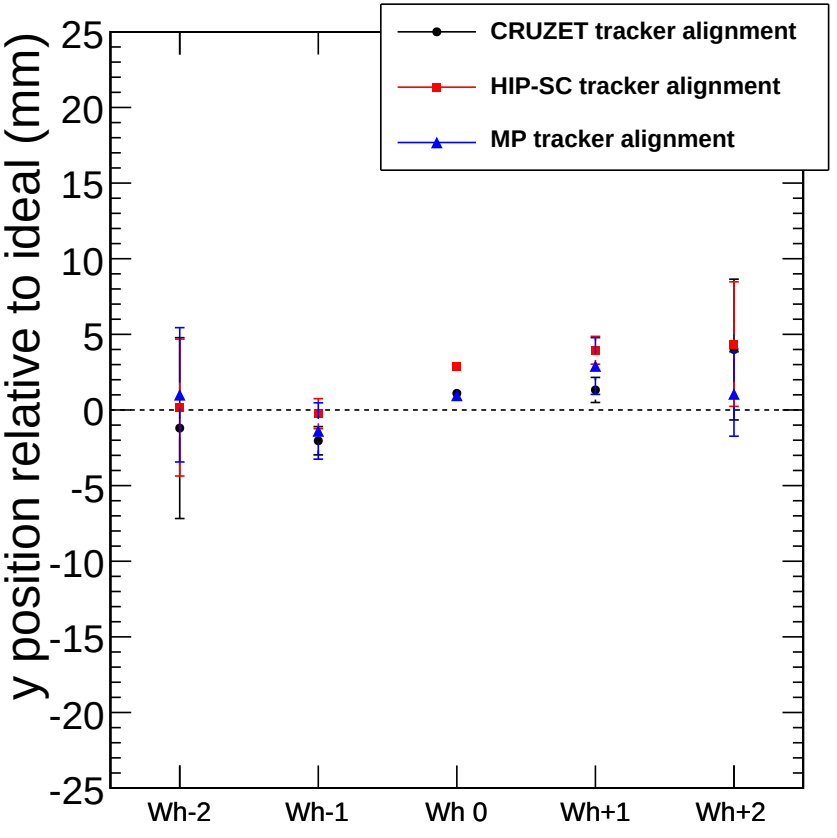

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